IRIS Lessons Learned
(insight from MUSE mission)

NASA PI Masters Forum #12
November 7, 2023

Gary Kushner
Lockheed Martin, Solar and Astrophysics Lab
PM: SMEX 2008 – IRIS
PM: Midex 2019 - MUSE

Agenda

- IRIS Science
- Mission Overview
- Class D Lessons Learned and Tailoring

IRIS Partners

LOCKHEED MARTIN

NASA Goddard Space Flight Center

SAO

NASA Ames Research Center

Stanford University

UiO : University of Oslo

Montana State University

Science & Technology Facilities Council Rutherford Appleton Laboratory

NSO

esa European Space Agency

NAOJ National Astronomical Observatory of Japan

NCAR National Center for Atmospheric Research

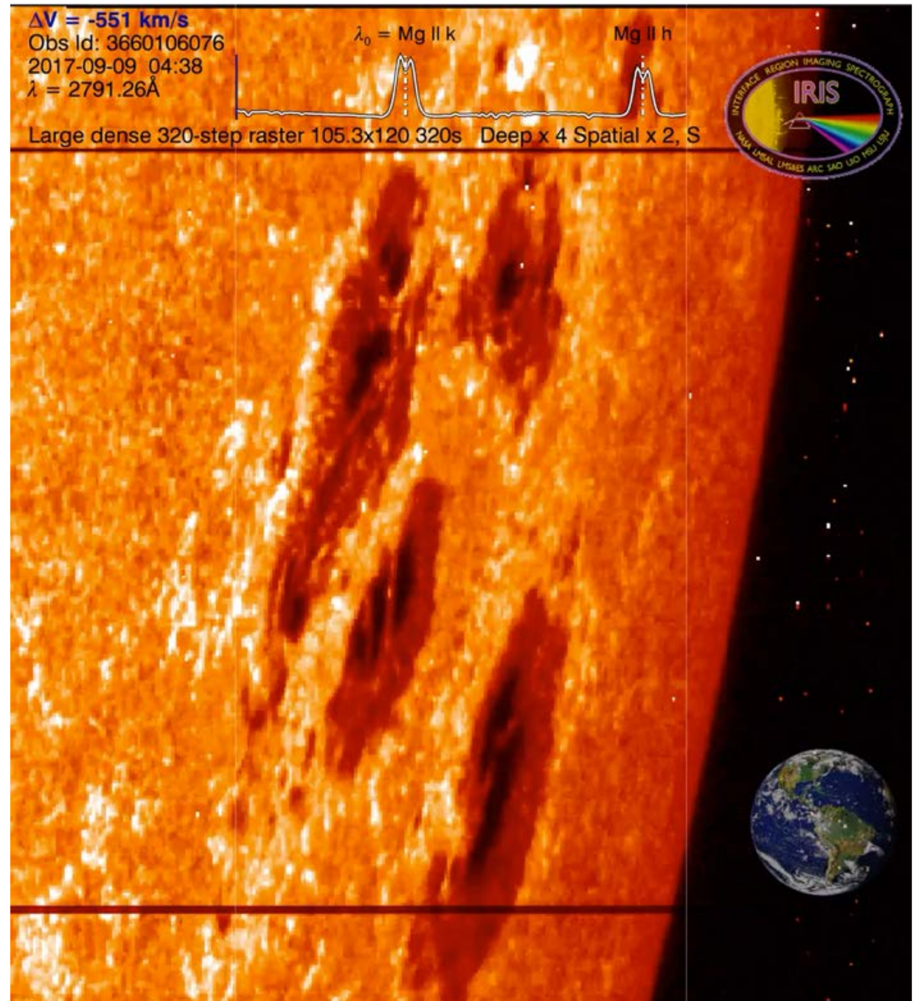
Berkeley University of California

MPS Max-Planck-Institut für Sonnensystemforschung Max Planck Institute for Solar System Research

Most Compelling Science Driver

To discover how an outer stellar atmosphere is energized

- The chromosphere is where most of the non-thermal energy that creates the million-degree corona and solar wind is released.
- This critical region has long been neglected because of its complexity. But now modern computers and new instrument capabilities can uncover the fundamental physical processes that occur there.
- ***In particular how non-thermal energy is generated and transmitted through the chromosphere and transition region into the corona.***

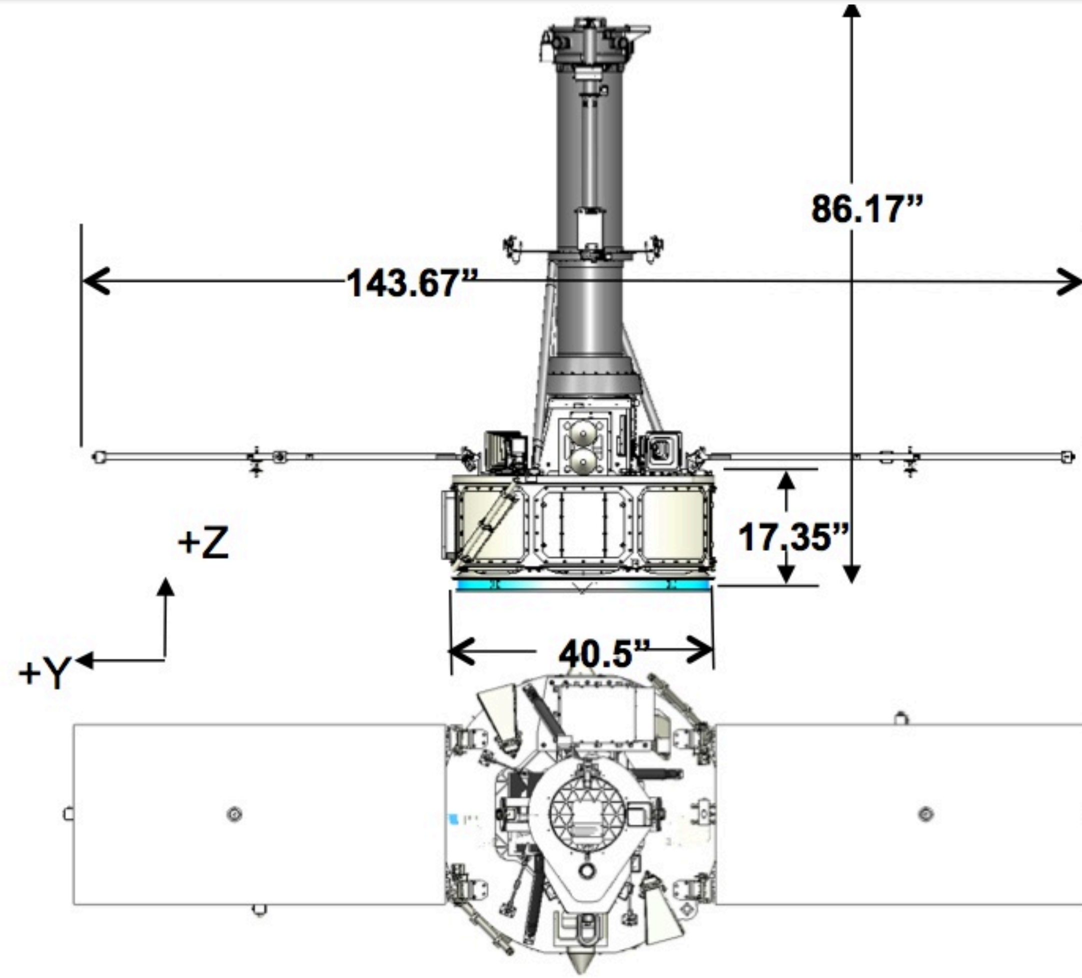


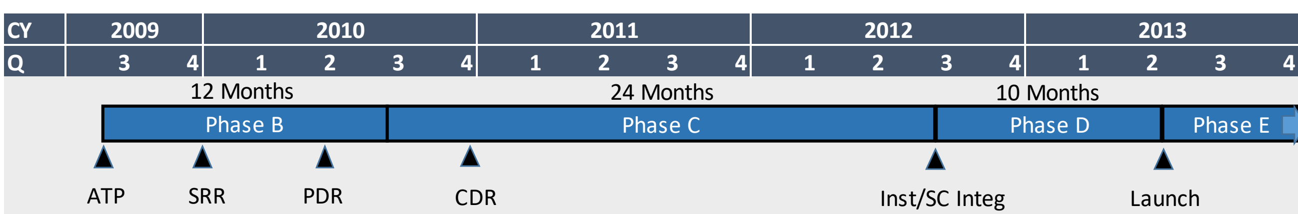
IRIS Science Summary

- **IRIS functions well: high-res spectra, images obtained daily**
- **>340 IRIS-related refereed papers published to date**
- **IRIS data available at http://iris.lmsal.com/search**
- **Some science highlights:**
  - Coronal heating:
    - First detection of resonant absorption of Alfven waves
    - Discovery of jets resulting from braiding
    - Detection of electron beams during nanoflares
    - New insights into formation of spicules, most ubiquitous solar jets, and their impact on transition region & coronal heating
  - Chromosphere:
    - Novel diagnostics using AI approach (1 millionx faster)
    - Heating from magneto-acoustic shocks, weak magnetic fields, and ion-neutral collisions
  - Reconnection:
    - Discovery of hot plasma (0.1 MK) in normally cool low atmosphere, proof for Ellerman bombs as reconnection events
    - Evidence for transition from slow to fast reconnection mediated by plasmoid instability
  - Previously “unresolved fine structures” are small 0.1MK loops
  - Flares and CMEs:
    - Evidence for non-thermal electrons in flares, tether-cutting as CME driver
    - Advance (40 minute) warning for flares using AI approach

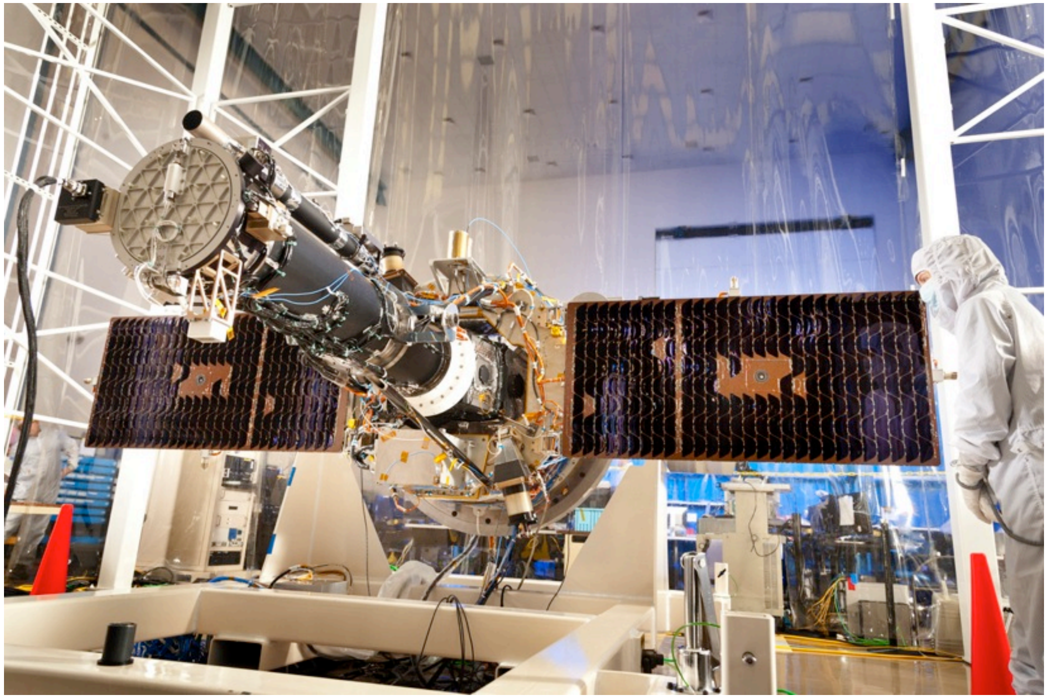
IRIS Mission

- **Launched June 27, 2013**
- **Launch Vehicle: Pegasus XL**
- **Solar Pointing**
- **Orbit: Sun synchronous, polar Orbit: 620kmx670km**
  - 7 months eclipse free viewing
  - Orbit Inclination: 97.89 deg MLT 6:00-6:05am
  - Orbit period: 97 min
- **Mass: 183 kg meas.**
- **Power: 342 W meas.**
- **Telemetry rate:**
  - 15 Mbps, 60Gb/day (X-band)
- **Recording capacity: 48 Gbits**
- **Mission Life: >2 Years**
- **Budget ~ $115M RY 2009**





IRIS Observatory



IRIS – What Went Well

- **Excellent communications between the Project Manager (PM), NASA's Explorer Program Office, PI, and NASA HQ**
  - Establish trusted relationship – ability to discuss "hot" items
  - Ability to "pre-negotiate" items
- **Very stable funding**
  - Explorers provided stable funding throughout all phases
  - Requires program to provide sufficient funding estimates and notification (533) of fund out dates
  - Recent lessons learned – funding issues and replans distract program team and eat resources
- **Combined/co-located team**
  - Instrument, spacecraft, and mission operations team in same area
  - Minimize team/management interfaces as much as possible
- **PI and Science Lead commitment 100%**
  - They managed requirements challenges
  - Managed Science Team, CO-Is and maintained focus on modelling, calibration, and tools
- **PI and PM relationship key**
  - Very frequent communication
- **Risk Management (even informal) key to keep team focused on top issues**
  - PI must be involved
  - Part of communication between team and PI, early indication of areas to apply MR "risk dollars"

IRIS – What Went Well p2

- **Early definition of requirements**
  - Lock majority of Level 1 and Level 2 requirements at SRR.
  - As a minimum, the top key driving requirements.
  - Very strong correlation between unstable requirements and cost growth
  - On these fast programs, Phase A is the period to close out most major trades.
  - Science Traceability Matrix (STM) and Mission Traceability Matrix (MTM) are used throughout the program, especially at SRR, PDR, and CDR
  - Example:
    - IRIS had 168 Level 2 requirements
    - Very stable during formulation phase: between SRR and PDR, about 8 requirements were significantly modified, about the same between PDR and CDR
  - Develop error budgets early (e.g. pointing, jitter, alignment, throughput…)
  - Two way traceability between Level 1 and Level 2 critical (buyoff with NASA at Level 2, HQ at Level 1). Very good traceability to level 3 (Instrument Performance). Very informal for Level 4 and lower – still have specs, but not forced traceability.

- **Class D implementation:**
  - SRB: were partners on team
  - Explorers and PI involved in selection
  - Members had deep skill set with sufficient Class D experience
  - Must address at institution too – e.g at LM, we tailored our internal processes, helped control scope and received executive management buy-in

IRIS – What Went Not So Well

- **IRIS had ~14 subcontracts/major vendors**
  - ~20% will have trouble, but you will not know which ones at the start
  - Perform risk based assessment of all vendors and estimate which ones require extra effort
  - Example: less mature comm vendor, determined early that extra support would be needed, allocated risk dollars to manage, was successful, even with risk dollars, was less expensive then alternate
  - Visit your top 2 or 3 frequently
  - Example: Held monthly review with top subcontractor/colleague, weekly reviews for high risk or critical path suppliers, monthly for all other key suppliers
  - Alert NASA customer earlier, rather than later, on issues that impact the schedule!
- **Had several anomalies:**
  - Integrated Avionics Unit (IAU) anomaly due to ICD miss with reaction wheels. Extra scrub of ICD may have caught.
  - IAU resistors blown due to mis-read specs of solar array release devices. Scrub by pyro engineer may have caught
  - X-Band transmitter oscillator de-bond during vibe; almost missed, cue from other program and Explorers office direction caught issue
  - Delay in EGSE/Test Consoles readiness; test system complexity can catch you off guard and delay program at single line flow
  - HOWEVER: good relationship with vendors in the first three cases allowed for very rapid turnarounds.
- **Class D tailoring: MAR, GOLD Rules, and EVM**
  - MAR – was flowed down, PAIP was supposed to be negotiated, e.g added cost for electronics fab
  - GOLD Rules – was supposed to be single step review and tailoring – ended up being line by line
  - EVM – standard gripe – not tailored to program size

Other – Class D Lessons Learned

- **PI/PM:**
  - Exercise your authority!
  - Participate in selection of SRB
  - Before kick-off, study and learn about:
    - Tailoring of MAR and GOLD Rules
    - NPR 7120.5 (program management) tailoring – very hard, but need to try
    - CDRL tailoring – especially content of each DRL
    - NPR 7150.2 (Software) tailoring
    - Requires early investment of time, but hard to do later once program in gear
    - These may seem esoteric to you, but are life blood at NASA, puts you on par for early discussions.
  - Learn some of NASA language – certain words have specific meaning: funding, baseline, replan
  - YOU have to manage the SRR, PDR, and CDR expectations
  - CLASS D is HARD – people default to Class B, requires constant vigilance and negotiation
- **Don't just talk about tailoring – get it written down! Especially CDRL and NPRs**
- **Early Risk Management process was also key**
  - Identified top two subcontracts for very early focus – led to early delivery of focal planes and cryocooler
- **PI role is key, we say it over and over, but it is true**
  - This is a 100% job – manage team, manage institution, manage NASA
  - Must trust PM, but still need to be informed
  - Must enforce clear lines of communication within team, and between institutions including NASA
  - Must push back and enforce Class D and insight versus oversight

Other suggestions

- **On IRIS, we performed a lessons learned review (survey) with the team before they dispersed. Suggestions from the team:**
- **Areas to improve/watch**
  - More aggressive tailoring of institution's processes
  - Make tool decisions early, get templates, guidance out
  - Develop core team, keep as much cradle to grave as possible
  - Be agile with staffing – pro-active with bad fits, be selective, be clear with going outside, cross-train so can handle if key personnel leave
  - Early resource planning essential, but be willing to revisit at key program milestones
  - Continuously promote small team culture – especially with new members, over communicate if not co-located
  - Lack of resources early resulted in reactive not proactive responses
- **Other**
  - Co-location and almost daily communication
  - Drive schedule discipline early in program. Lock down design and hold to baseline
  - Emphasize early physical and mathematical models
  - Trade level of assembly for test (risk vs time vs resources)
  - Find out who in NASA community is using similar technology or same vendors
    - IRIS Examples: GRAIL, LADEE, MAVEN (battery, reaction wheels, comm system)
    - Lessons learned; available hardware to borrow; avoid vendor resource competition
  - Team also provided technical improvement ideas for hardware designs and test equipment

MUSE Updates

- **Some things have changed over the past few years**
- **NPRs have become institutionalized and more rigidly enforced**
  - Learn them early.
- **Supply chains! Despite indications in the media, supply chains and long lead procurements will eat your program alive. As soon as requirements are known, start procurement or solicitation efforts**
  - NASA equal partner in this and will approve early long lead items
  - EEE parts are insane, start as soon as possible, vendor dates are almost meaningless
  - Industry consolidation continues including parts obsolescence
- **Shape your proposals to allow more realistic funding profile should you need bridge funding**
  - It takes time to get a fully certified proposal through all NASA reviews. Assume some type of provisional or bridge funding may be required. If you "peanut butter spread" then you may not have sufficient funding to start some long lead procurements.
- **Look at your past programs and then be very flexible – for example staffing**
  - We are bringing new and younger people on the team, this requires focus on program culture and more mentoring than originally planned.
  - More frequent all-hands, more inclusion in team reviews
- **EVM gets more complicated every year:**
  - We held more than 8 pre-EVM planning workshops with NASA SME to plan and do some tailoring

MUSE Updates p2

- **Continued excellent relationship with NASA EXP and HQ**
  - Similar relationship with PM and MM – early notification of potential issues
  - Talk through issues such as contracting and material information delays
  - Open to suggestions, such as starting Phase C/D costing items with draft SOW and RFP

- **Following lessons learned from IRIS**
  - More pro-active personnel management

- **Foreign travel is brutal**
  - Plan way ahead before your first trip
  - Need to take State Department training and get their clearance for travel

- **Still working through the hybrid work environment**
  - Desire for more in-office/lab interaction

BACKUP

Contributions to Project Success

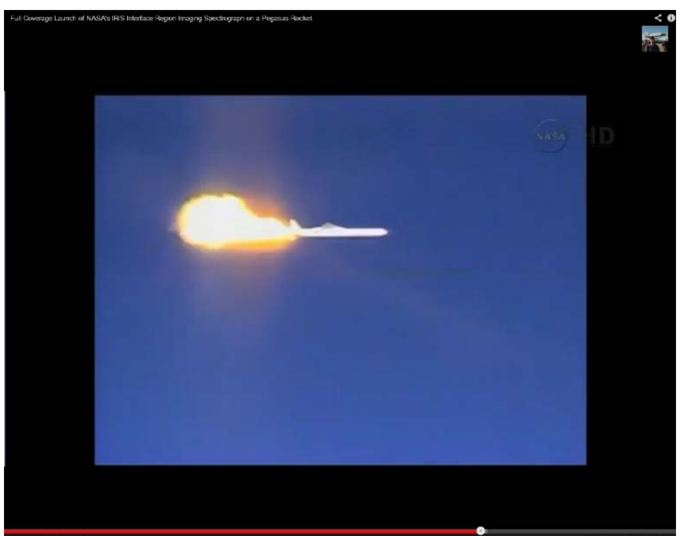
- **Co-location of team–(as much as possible); PI, PM, science team members critical**
  - If not, must over communicate and use excellent sharing tools
- **Excellent working relationship between PM and MM and Explorers office**
  - Bring up issues as soon as possible to minimize any surprises
  - Ability to share early information with time to follow up with details and resolution plans if needed
  - Explorers office treated as key and trusted member of Project Team {IRIS Example – comm box}
- **Team composition**
  - Small team, “many hats,” cross-train, keep work in-house and in-team
  - Team agility – people with good judgment are as important as good processes
  - Designers, Architects – experience with build and test – design for X
  - Quality is part of team and solutions, not just monitor, audit, and enforce
- **Communication critical at all levels**
  - Visit subs, key team members, and hold more TIMs than planned
    - Prior to visits – “why am I doing all this travel for a 4 hour meeting”
    - After visit/TIM – “I can’t believe how important that meeting was to clear up …”
  - Perform vendor risk based assessment and allocate reserve funds as soon as needed
    - IRIS example: Identified less mature vendor, figured out areas where company could truly help, estimated cost and allocated cost reserves up front, worked with vendor throughout to provide assistance in board development and test
  - Tailoring of procedures and processes – breaks command and control structure and captures executing team’s inputs

IRIS Mission Architecture

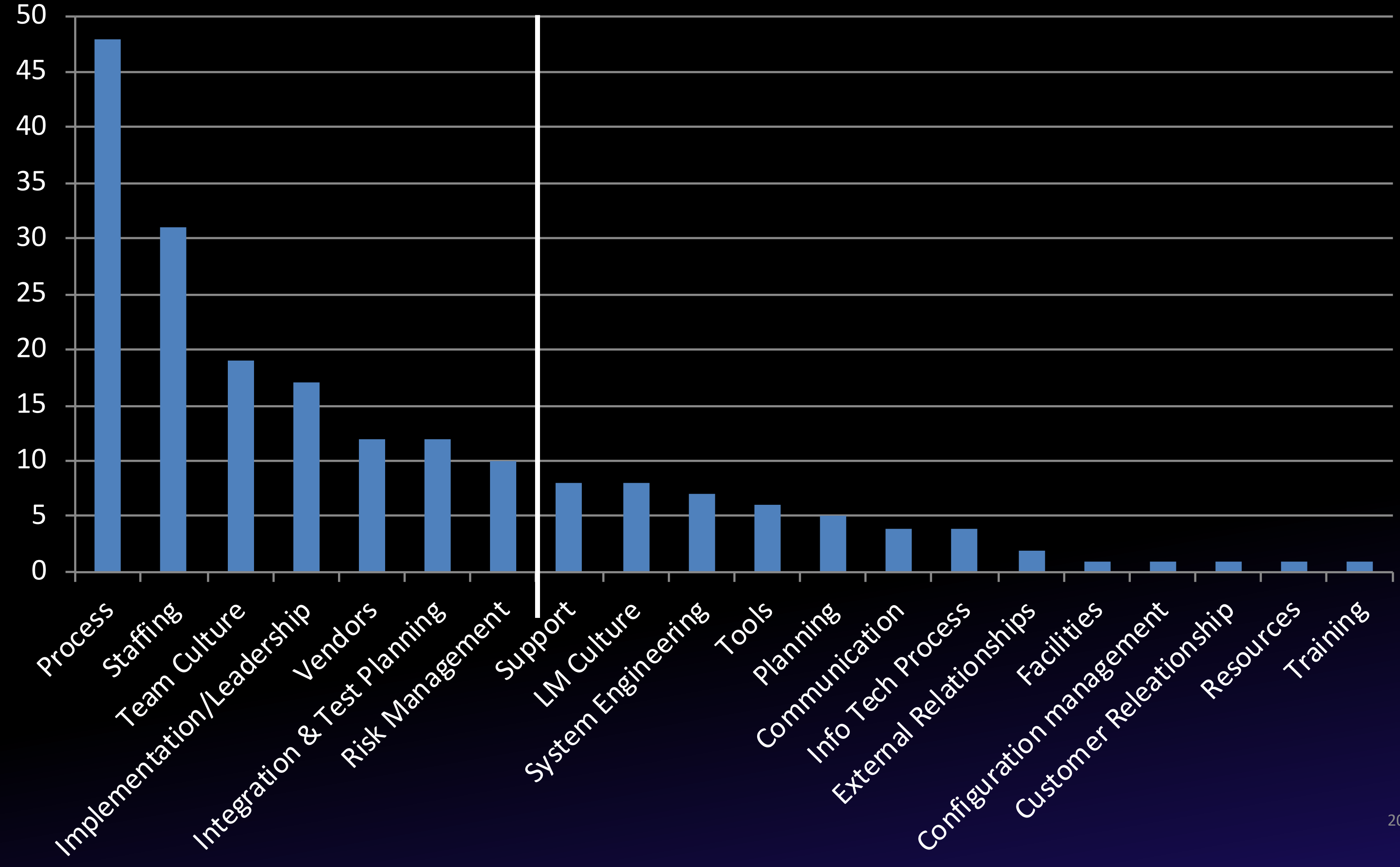
Launch Day

Plane and rocket preparing for takeoff

Longest 5 seconds ever



Distribution of Lessons Learned Survey Categories

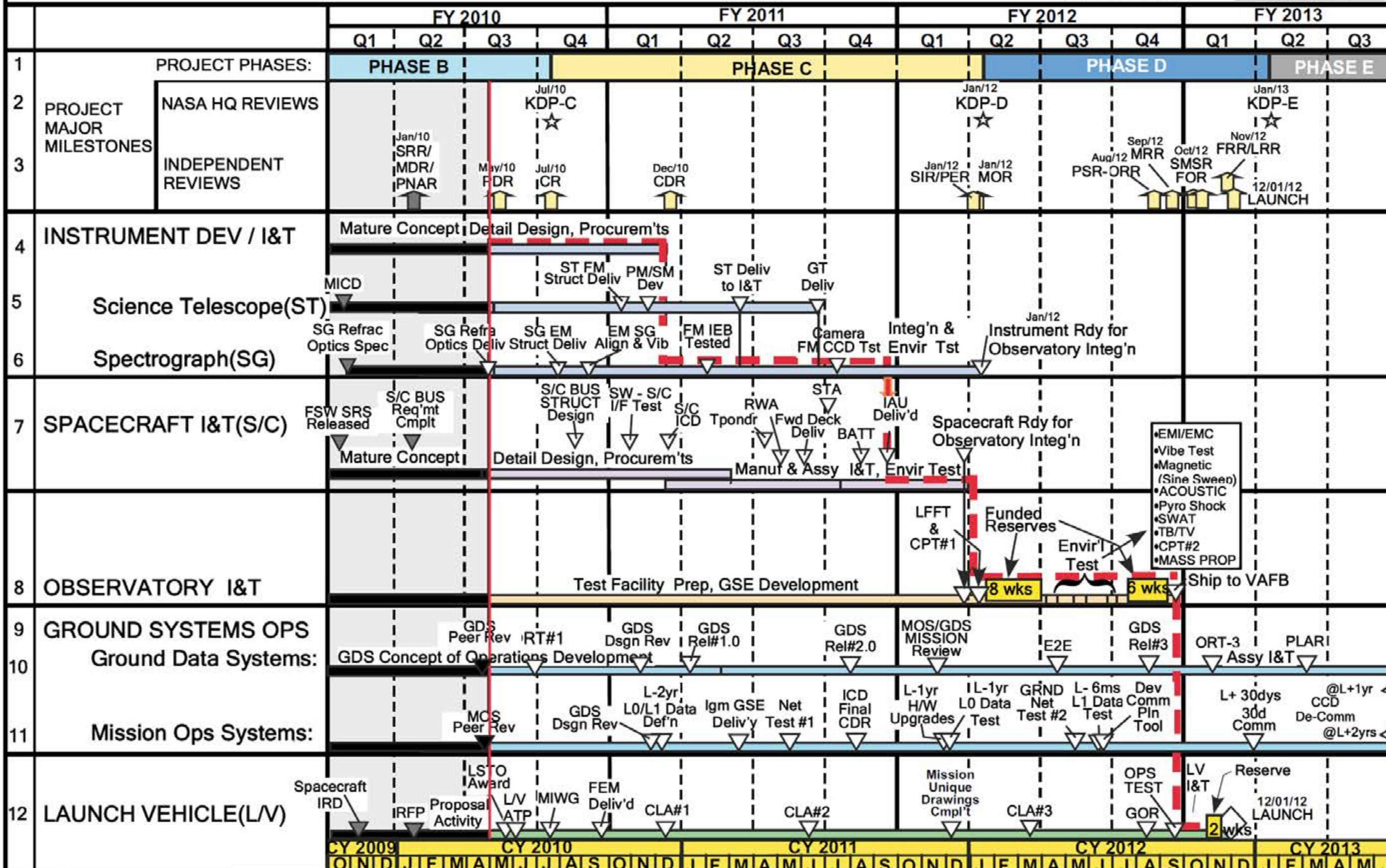


INTERFACE REGION IMAGING SPECTROGRAPH (IRIS)

PROJECT MASTER SCHEDULE

GODDARD SPACE FLIGHT CENTER
APPVL RESP: Gary Kushner

BASELINE AS OF: TBA
LAST SCHED CHG:
STATUS AS OF: 04/30/10



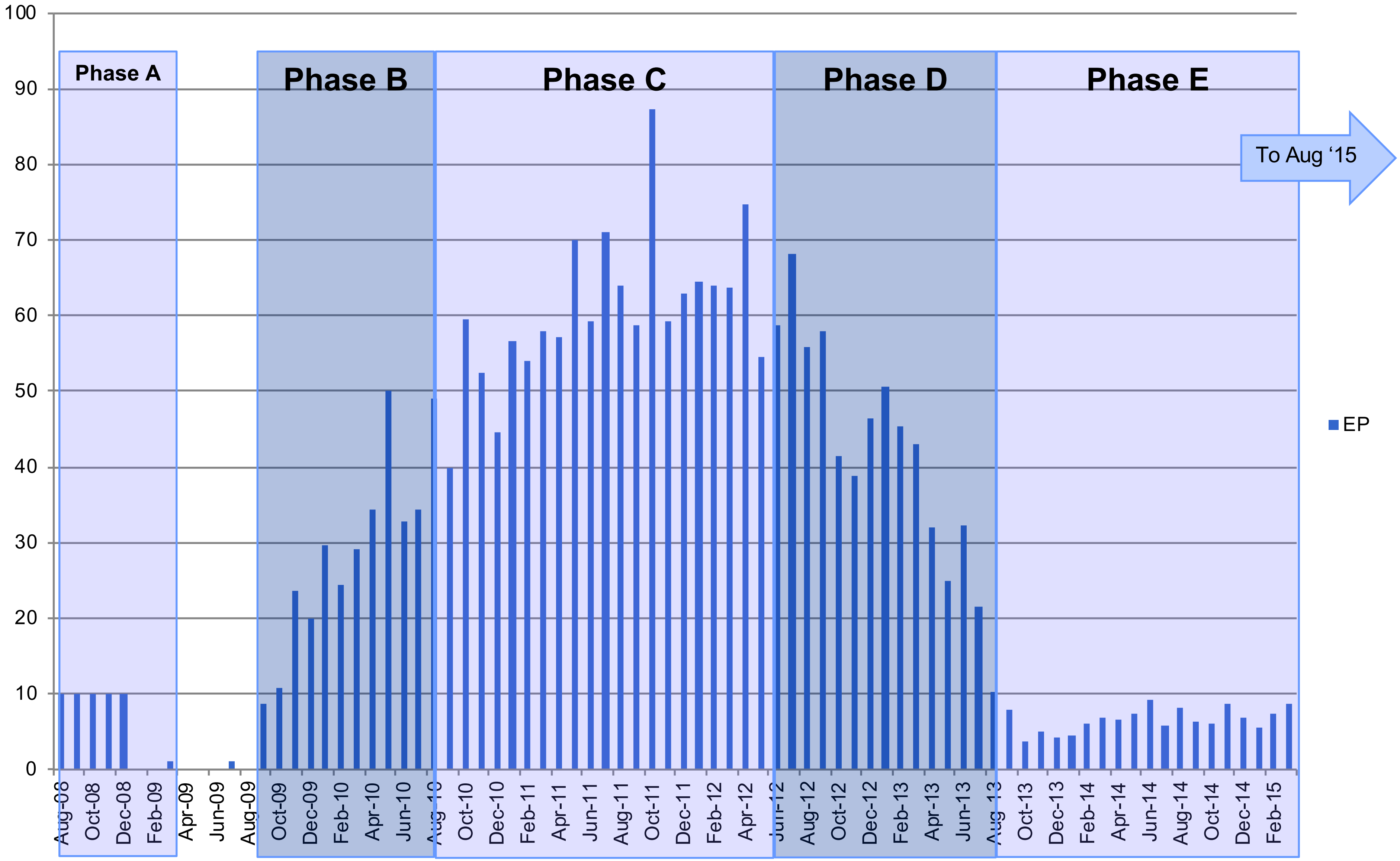
NOTES:

Critical Path:

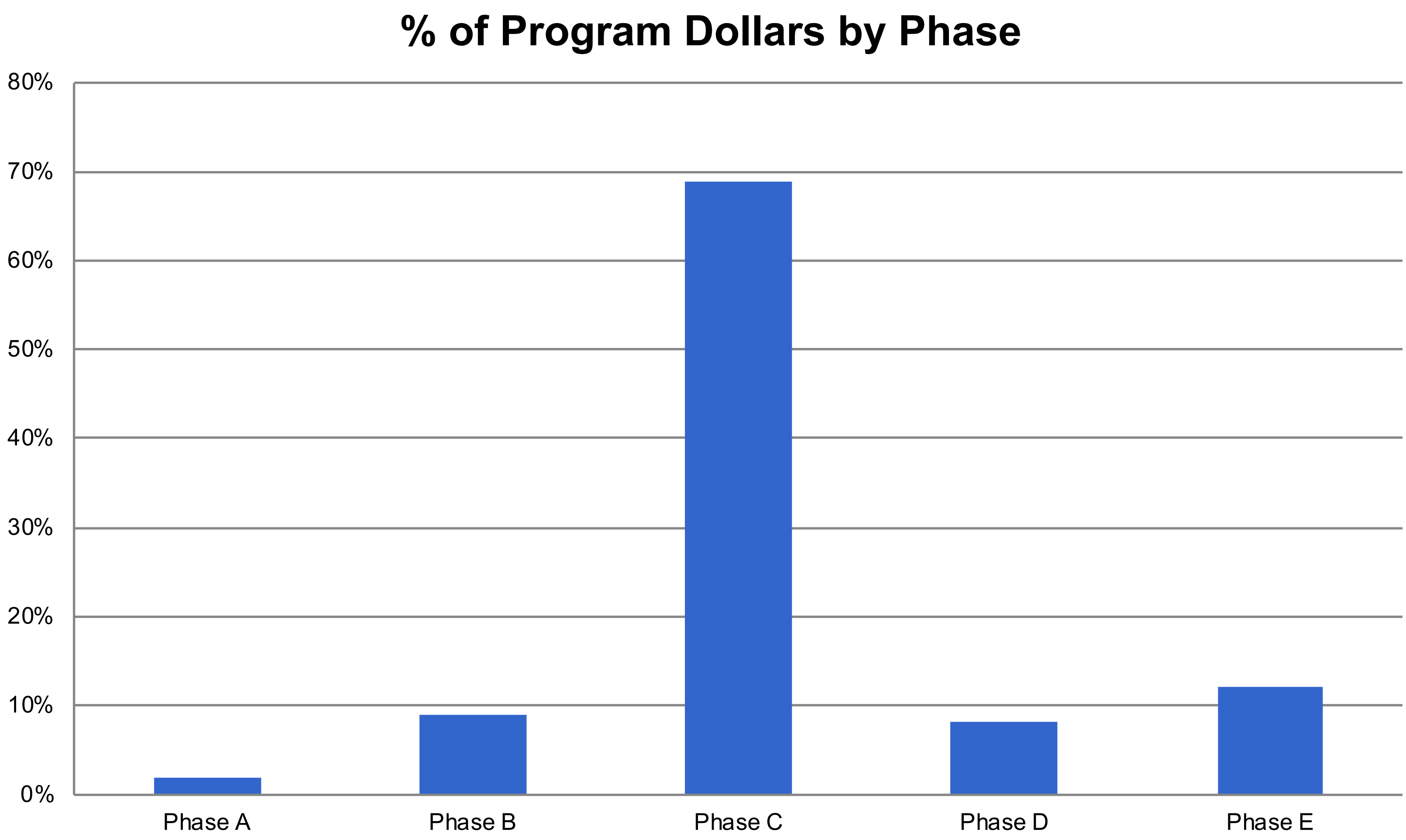
FIG:

05/14/10 09:00 H

IRIS FTE Profile Over Program Lifecycle



Example Program Costs by Phase



Example Program Costs By WBS

WBS	Description	
1.0	Project Management	7%
2.0	Systems Engineering	5%
3.0	Safety & Mission Assurance	5%
4.0	Science/Technology	3%
5.0	Instrument	34%
6.0	Spacecraft	37%
8.0	Launch Vehicle/Services	1%
9.0	Ground Data Systems	1%
10.0	Systems Integration and Testing	8%
11.0	Education and Public Outreach	0%
	Total	100%